Notes on the Biology and Host Specificity of *Acentria nivea* (=*Acentropus niveus*)[1, 2]

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ABSTRACT

The accidentally introduced European aquatic moth, *Acentria nivea* (Olivier), was reared in the laboratory for at least three generations. All females reared during this study had rudimentary wings and were flightless though winged flying females have been reported in North America. The larvae were fed leaves of Eurasian watermilfoil (*Myriophyllum spicatum* L.), one of the most important submersed weeds in the United States. High water temperatures were tolerated by the larvae for short periods, but they required temperatures below 22 C for development. *A. nivea* larvae in no-choice tests fed on a variety of aquatic plants that are summarized along with the plant species reported in the literature as natural or laboratory hosts.

INTRODUCTION

Acentria nivea (Olivier), a small (12 mm) aquatic moth, is a possible biological control agent of Eurasian watermilfoil, an introduced submersed weed. Although *A. nivea* is native to Europe, it was apparently introduced accidentally into North America. It was first collected at Montreal, Quebec, Canada, in 1927 (11) and was subsequently found along the St. Lawrence River or in the general vicinity of Lakes Ontario and Erie (7). Moths were first collected in Massachusetts at Barnstable in 1949[3] and later at other locations in that state (12, 13). Batra (3) reported seeing museum specimens that were collected in 1963 at Middleton, Wisconsin. The species was also collected at Bailey's Harbor, Door County, Wisconsin, in 1966..[3] Larvae were collected in 1977 in Ontario, Canada, at White Lake, which is in the Ottawa River drainage system.[4]

Several other species included in the pyralid subfamily Schoenobiinae are associated with emersed and semiaquatic plant species in the Poaceae (Gramineae) and the Cyperaceae, for example, *Phragmites, Glyceria, Scirpus, Carex,* and *Eleocharis.* The larvae of these species are internal borers and are not truly aquatic like those of *A. nivea.*

The biology of *A. nivea* has been thoroughly studied in Europe (4, 9, 10). Batra (3) studied it in the U.S. and also reviewed the literature. As a result of her studies, she concluded that the species might have potential for use in Florida against the two submersed weeds, Eurasian watermilfoil and hydrilla (*Hydrilla verticillata* (L. fil) Royle), but that further host specificity studies were necessary. The objective of this study was to establish a laboratory colony of *A. nivea* and to conduct host specificity studies. Observations made during the field collection of *A. nivea* are also reported.

METHODS AND MATERIALS

Larvae were collected on northern watermilfoil (*Myriophyllum exalbescens* Fernald) in the St. Lawrence River at Lake St. Lawrence, Robert Moses State Park, near Massena, New York, in June and September 1978. The June collections were made in front of the Barnhart Marina and the adjacent public bathing beach by snorkeling. The September collections were made at various locations in the vicinity of Long Sault Dam and the Barnhart Marina. Small battery-operated minnow bucket aerators were used to aerate the water in plastic bags containing watermilfoil stems and larvae several times during the combined auto and air trip to Gainesville in June. They were also used the night before departure in September.

Various methods were used to maintain a colony in quarantine for 1.5 years at the Biological Control Laboratory, Division of Plant Industry (DPI), Florida Department of Agriculture and Consumer Services, Gainesville. The most successful method was to hold them in aquaria of various sizes or in 3.8-l (1 gal) glass jars in temperature cabinets at 18-22 C with a 16 hour photophase. The contain-

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[3]Charles P. Kimball, Barnstable, Massachusetts. Personal Communication.

[4]Suzanne W. T. Batra, AR, SEA, USDA, Beltsville, Maryland. Personal Communication.

ers were occasionally aerated with air stones attached to aquarium pumps and some of the water with frass and decaying plant material was siphoned from the bottom and exchanged with fresh water. The larvae were fed Eurasian watermilfoil, herein called milfoil, that was collected at Crystal River, Florida.

No-choice tests with the larger larvae (10-13 mm) collected in June were conducted by placing individual larvae in culture tubes, 150 x 20 mm, with a 10 cm section of test plant stem. The tubes were covered by pieces of nylon organdy held in place by plastic caps and were kept in a rearing room at about 25 C with fluorescent lighting at a 16 hour photophase. The degree of feeding was evaluated subjectively because of the various shapes of the test plant leaves. Thus, feeding approximately equal to that on milfoil was designated "moderate" (equal to about 50% of the milfoil leaf material being eaten) and a few feeding spots with no appreciable damage to the plant was designated "minor." The duration of the test was two weeks and the stems of the species which were consumed were changed twice each week. At the end of the test the larvae were added to the rearing colony. The following plant species were tested (number of larvae used in parentheses): alligatorweed (*Alternanthera philoxeroides* (Martius) Grisebach) (3); fanwort (*Cabomba caroliniana* Gray) (3); slender spikerush (*Eleocharis acicularis* (L.) Roem. & Schult.) (4); hydrilla (5); water pennywort (*Hydrocotyle umbellata* L.) (3); frogbit (*Limnobium boscii* Rich.) (2); creeping waterprimrose (*Ludwigia repens* Forst.) (3); parrotfeather (*Myriophyllum aquaticum* (Vell.) Verdc.) (2); Eurasian watermilfoil (5); southern naiad (*Najas guadalupensis* (Spreng.) Magnus) (6); watercress (*Rorippa nasturtium-aquaticum* (L. Hayek) (2); Illinois pondweed (*Potamogeton illinoensis* Morong) (2); mermaidweed (*Proserpinaca palustris* L.) (2); mermaidweed (*P. pectinata* Lam.) (2); salvinia (*Salvinia rotundifolia* Willd.) (3); cattail (*Typha* sp.) (1); dwarf arrowhead (*Sagittaria subulata* L). Buchenau) (4).

Although actual choice tests were not conducted, stems of hydrilla, southern naiad, Illinois pondweed, and coontail were mixed with those of milfoil in some of the colony rearing jars with the June larvae. In order to determine potential development on species other than milfoil, 20 small larvae (3-4 mm) from the September collection were placed into each of five jars containing individually either hydrilla, Illinois pondweed, coontail (*Ceratophyllum demersum* L.), Brazilian elodea (*Egeria densa* Planchon), or milfoil. Also one egg batch obtained from the colony in Spring 1979 was placed in a jar with Illinois pondweed to determine if the newly emerged larvae (neonates) could develop on it. A second species of pondweed (*P. perfoliatus* L.) was added later, when the larvae were larger, because of a shortage of Illinois pondweed.

RESULTS AND DISCUSSION

Field Observations

The June 19 field collection yielded additional information to that already reported by Batra (3) who conducted studies at the same locality in 1975-1976. The surface water temperature was 17 C and most northern watermilfoil plants had not yet started to grow, although new growth was apparent on a few plants in shallow water. The majority were rooted, upright, perennial plants with multiple 13-50 cm tall shoots. These plants were about 30-100 cm apart and were generally grouped into isolated small clusters at 1.5-2.0 m depths. Most plants were covered with filamentous algae and other debris. The clumped distribution of the perennial plants and their upright growth habit makes it difficult to survey them when they can not be seen from the surface. Batra (3), who collected in the same area from a boat with a rake, concluded that the plant population overwintered as broken shoots or propagules that had sprouted by June, however, only a minority of the plants overwintered that way.

Although northern watermilfoil was the dominant species, there were small areas where coontail was abundant. A few scattered plants of waterweed (*Elodea canadensis* Michx.) were also collected.

One or more larval cases of *A. nivea* were attached to almost all watermilfoil plants. Cases were also found on coontail and a few on waterweed. However, the waterweed had been with watermilfoil overnight, before the plants were examined, so there was a possibility that the larvae had transferred. Most of the larvae were large (10-13 mm), but smaller larvae (5-7 mm) were also present.

A population of active adults was observed at a shallow inlet from 2200-2400 on both June 21 and 22. This was a month earlier than the adults were reported by Batra (3) at the deeper Barnhart Marina location. Males were observed flying in wide circles just above the surface of the water and were collected by submersing a net and then raising it slightly as they passed over. They did not attempt to fly out of the open net but kept flying around the edge. They were easily transferred from the net by dipping a cup into the water directly behind them as they flew. They entered the cup along with the water. They were also handled in this manner in the laboratory. Only males were found even though both submersed and emersed plants were searched for females. No adults were attracted to blacklight traps placed on the shore and about 75 m away although they were reported to be attracted to blacklights and incandescent lights (12, 13).

Biology and Rearing Observations

The male *A. nivea* was a small, winged, grayish-white moth, but the gray female had reduced wings and was flightless. Females that have normal wings and can fly have been reported (4, 9, 13), but none were obtained during our rearing. The larvae did not have gills as do the larvae of the more common genus *Parapoynx*. They also differed from most *Parapoynx* larvae by the type of shelter they built. *A. nivea* usually tied together several leaves of milfoil to form a stationary shelter from which it fed or from which it exited to feed and new shelters were often produced. Larvae were also often found in the leaf buds which formed natural shelters. Most *Parapoynx* larvae cut leaves from their host plants to form cases that they carry with them and from which they feed. Both *Parapoynx* and *A. nivea* larvae can also be found feeding within the stems of their hosts. Larvae of the polyphagous *Synclita obliteralis* (Walker) occasionally fed on milfoil in our outdoor pools. It was similar to *A. nivea* in lacking gills but it lived in an air-filled case and had a characteristic dull-white skin compared to the transparent skin of *A. nivea*. The mature *A. nivea* larva excavated one side of the stem and then attached to the stem a tightly woven white elongate cocoon which was filled with air from the damaged stem. If the stem became waterlogged, the pupa died.

Most females in the laboratory emerged at night or in the late afternoon. They rested on the water's surface and at night they lifted their abdomens in the air and presumably released a pheromone to attract the flying males. Females generally died before the second night after emergence or else were very weak by then. When females were disturbed they swam rapidly on the surface with the aid of specially adapted middle and hind legs. Disturbed females attempted to submerge, but since the body scales are apparently hydrophobic, they were unable to submerge unless they held onto stems. Females were observed clinging to underwater stems where they oviposited single clusters of yellowish ovate eggs. Eggs were also deposited on styrofoam floats. Berg (4) detailed the biology and developmental times and illustrated the swimming legs, genitalia, mouthparts, and various life stages.

The biologies reported for *A. nivea* have been based upon field-collected material. It has not been successfully reared previously. One reason is that the long developmental time results in staggered emergences; only a single or a few adults emerge on the same night and they die or are weak by the second night. The adults that emerged in January 1979 from small larvae collected in September 1978 produced at least three generations by January 1980. Berg (4) reported, however, that there was only one generation per year in the field. Attempts to monitor the colony to obtain fertile eggs for experiments were unsuccessful except one time when a fertile egg mass was found. Larvae were produced only in containers that were left undisturbed. Many of the field-collected larvae from the June collection crawled out of jars and spun cocoons among paper toweling on the cage floors. None of these survived. Nigmann (9) also reported that larvae crawled out of the rearing containers, and Treat (13) mentioned that two larvae, which eventually died, made cocoons under the lid of a holding jar. Initially we thought that this behavior was a response to low dissolved oxygen but it continued even when the jars were aerated. It was probably avoidance of high temperatures since the jars were then being held above 24 C, which subsequent observations indicated was too high. The larvae withstood high temperatures (at least 40 C) for short periods during equipment breakdowns, but prolonged exposure above 22 C retarded development or led to death. Larvae can escape high surface temperatures in nature by moving deeper into the water but in the laboratory containers this was not possible. Larvae were not observed crawling from containers after we began holding them below 22 C.

A low dissolved oxygen concentration was apparently important, however, during transport of field-collected larvae in plastic bags densely packed with plant material. Larvae became immobile within a few hours if the bags were not exposed to light. Most of these larvae recovered when the bags were aerated during and after the trip to the laboratory. During long dark periods, for example during shipping, oxygen would be critical; it would be necessary to either provide oxygen or to include only a small number of plants in a large volume of water. In our laboratory rearing, constant aeration was not necessary.

A fungus, *Achyla* sp., was isolated from dead larvae in our colony. Its infectivity was not studied but it was probably saprophytic.[5]

Host Specificity Studies

The no-choice test confirmed the reports of other authors that *A. nivea* feeds on a variety of plants. The plant species consumed in our test are summarized in Table 1 along with the plant species reported by other authors to be associated with *A. nivea*. Moderate to heavy feeding was observed in this test on hydrilla, parrotfeather, milfoil, southern naiad, Illinois pondweed, and both mermaidweeds. Southern naiad and Illinois pondweed were especially damaged. Only minor feeding occurred on creeping waterprimrose, watercress, and fanwort, though the latter species has a growth form and a leaf structure similar to those of milfoil. There was no feeding on alligatorweed, waterpennywort, frogbit, dwarf arrowhead, cattail, and slender spikerush, though relatives of this latter species are hosts of other schoenobiine moths. Salvinia leaves were not eaten, but the roots were always severed. Although the larvae in this test fed on parrotfeather, in Batra's (3) they did not.

Large larvae given a choice of coontail, hydrilla, slender naiad, Illinois pondweed, or milfoil fed and made cases on all of them. Small larvae confined with only one plant species developed and made cocoons on Illinois pondweed, hydrilla, coontail, Brazilian elodea, and milfoil. These cocoons were then placed together to obtain mated females. An egg batch with emerging larvae was placed on Illinois pondweed and medium sized larvae were obtained. This result combined with the preceding one leaves little doubt that the literature reports that pondweeds are host plants are valid (4, 6, 9). Possibly not all of the species listed in Table 1 are true or even potential host plants but they do confirm a broad feeding range and indicate a varied host range since eight plant families are represented.

CONCLUSIONS

The various host records reported in the literature and the results of our tests leave little doubt that *A. nivea* is not specific to milfoil and that it has a relatively broad potential feeding range. Since the collection records indicate that it is apparently increasing its distribution, it may eventually arrive at most milfoil locations. Whether it should be introduced for biocontrol of milfoil prior to the natural arrival

[5]Mr. Gerard Thomas, Diagnostic Service for Insect Diseases, University of California, Berkeley, California. Personal Communication.

TABLE 1. A LIST OF PLANTS ASSOCIATED WITH *Acentria nivea* (OLIV.) EITHER IN NATURAL HABITATS OR IN LABORATORY STUDIES.

PLANT FAMILY Common Name	Scientific Name	Relationship[a]	Record[b]
CERATOPHYLLACEAE			
coontail	*Ceratophyllum demersum* L.	C R F	4, 9, * 13, * 3, 7
ELATINACEAE			
waterwort	*Elatine americana* (Pursh.) Arn.	F	13
HALORAGACEAE			
northern watermilfoil	*Myriophyllum exalbescens* Fernald	C R	3, * 3
Eurasian watermilfoil	*M. spicatum* L.	C, F R	8 3, *
parrotfeather	*M. aquaticum* (Vell.) Verdc.	F	*
mermaidweed	*Proserpinaca palustris* L.	F	*
mermaidweed	*P. pectinata* Lam.	F	*
HYDROCHARITACEAE			
Brazilian elodea	*Egeria densa* Planchon	F	*
waterweed	*Elodea canadensis* Michx.	C R	4, † 4
hydrilla	*Hydrilla verticillata* (L. fil) Royle	R	3, *
NAJADACEAE			
southern naiad	*Najas guadalupensis* (Spreng.) Magnus	F	*
POTAMOGETONACEAE			
curly leaf pondweed	*Potamogeton crispus* L.	C	10
Illinois pondweed	*P. illinoensis* Morong	R	*
sago pondweed	*P. pectinatus* L.	C	9
pondweed	*P. lucens* L.	C	6
pondweed	*P. gramineus* L. (as *P. heterophyllus* Schreb.)	C	9
pondweed	*P. perfoliatus* L.	C	4, 9
pondweed	*Potamogeton* sp.	C	4
eelgrass	*Zostera* sp.	C	9
TRAPACEAE			
water chestnut	*Trapa natans* L.	C	9
ZANNICHELLIACEAE			
horned pondweed	*Zannichellia palustris* L.	C	9

[a] C = Immatures Collected; R = Immatures Reared; F = Fed Upon in Laboratory.
[b] In Literature Cited; * = Our No-Choice Tests; † = Batra pers. comm.

will need to be decided by individual states. We speculate that the long development period and the limited mobility of the flightless females of *A. nivea* will limit the buildup of large populations to host plants that are themselves at a high density. At high densities even the most beneficial native plant species are usually considered nuisances so that damage by *A. nivea* might be acceptable. If a dense stand of a plant species such as pondweed or naiad provided food for waterfowl, the feeding by the waterfowl would devastate the *A. nivea* population and prevent it from increasing. Although winged females are sometimes produced their occurrence is apparently sporadic. They would increase the mobility of the species, but their migration might help to reduce the high population of *A. nivea* after the decline of its principal host plant.

Populations of *A. nivea* would probably also be limited by natural enemies. Although an unidentified parasitic ichneumonid wasp from the pupa and a phorid fly possibly from the pupa were reported in a European study, other natural enemies listed were generalized predators such as water bugs, water mites, water beetles, spiders, fish, and bats (9). A fungus disease was also listed (9). Batra (3) reported that planarians were egg predators in her U.S. rearings. Since most aquatic communities include large numbers of these generalized predators and also contain diseases, *A. nivea* populations would be highly vulnerable to natural enemies.

The preceding arguments against the possibility of *A. nivea* becoming a noxious species also apply against it being of great benefit for biological control of milfoil or other host plant species. In addition, the observations of Nigmann (9) and Batra (3) that the larvae do not feed on algal covered leaves indicate that a large proportion of a milfoil mat would not be attacked by *A. nivea* larvae, especially in Florida. The top layer of milfoil stems at Crystal River was heavily covered with algae by at least midsummer. If, however, a complex of agents is desired for control of milfoil, as will probably be necessary, then *A. nivea* could be considered for that complex, especially since no substantial numbers of native moths have been found or reported on it. For example, only small numbers of *Parapoynx allionealis* (Walker) and *P. obscuralis* (Grote) were found on the milfoil collected at Crystal River as food for our colony, and only a few *P. badiusalis* (Walker) larvae were found on milfoil plants in a study at Currituck Sound, NC (2). There are no reports of other lepidopteran species on milfoil in the U.S.

Larvae of *A. nivea* preferred leaves of milfoil, but they did girdle stems breaking off small fragments. Although these fragments might form new shoots and aid in the spread of the plant as suggested by Batra (3), the natural spread of milfoil once it invades a waterway is so efficient that the effect of *A. nivea* feeding should be of little consequence. Stems are broken by wave action and by man's activity, and there are autofragmentation periods when the stems break apart naturally (1).

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